(12) UK Patent Application (19) GB (11) 2 199 404 (13) A

(43) Application published 6 Jul 1988

(21) Application No 8627611

(22) Date of filing 19 Nov 1986

(71) Applicant
Lindley Flow Technology Ltd

(Incorporated in United Kingdom)

"Flowtech House", Listerhills Science Park,
Campus Road, Bradford BD7 1HR

(72) Inventor
John Iain Raw

(74) Agent and/or Address for Service
Haseltine Lake & Co
Hazlitt House, 28 Southampton Buildings,
Chancery Lane, London, WC2A 1AT

(51) INT CL⁴
G01N 21/43

(52) Domestic classification (Edition J):
G1A D10 D4 DR G10 G17 G7 P10 P16 P17 P1
P9 R6 R7 S3 S4 S5 T14 T24 T2 T3
G2J 12
U1S 1270 1457 1762 1889 2159 2318 2323 G1A
G2J

(56) Documents cited
GB 1301082

(58) Field of search
G1A
G2J
Selected US specifications from IPC sub-class
G01N

(54) Refractive index measuring device

(57) The device includes: a light source (1); guide means (2) for guiding light from the light source into a prism (3), the prism having one face in contact with a medium (4) whose refractive index is to be measured; means (5) for extending the light path of outgoing light from the prism (3) which light has undergone total internal reflection at the prism face; and a linear array (6,7) of optic fibres acting as a detector for the outgoing light and guiding the detected light to a decoder and display unit (8). The device utilises the principle that when total internal reflection occurs at the face of the prism (3) in contact with the medium (4), the angle of reflection depends on the refractive index of the medium (4). The detected light can hence be processed by the decoder and display unit (8) to produce a refractive index value. The decoder and display unit (8) may be dispensed with, a display being given directly by the illuminated end(s) of the optic fibres. The device may be used to measure an oil/water emulsion in hydraulic fluid lines of underground mining machinery.

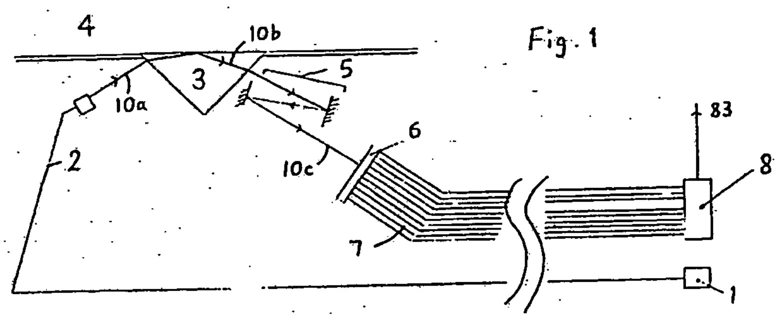


Fig. 1

GB 2 199 404 A

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

Fig. 1

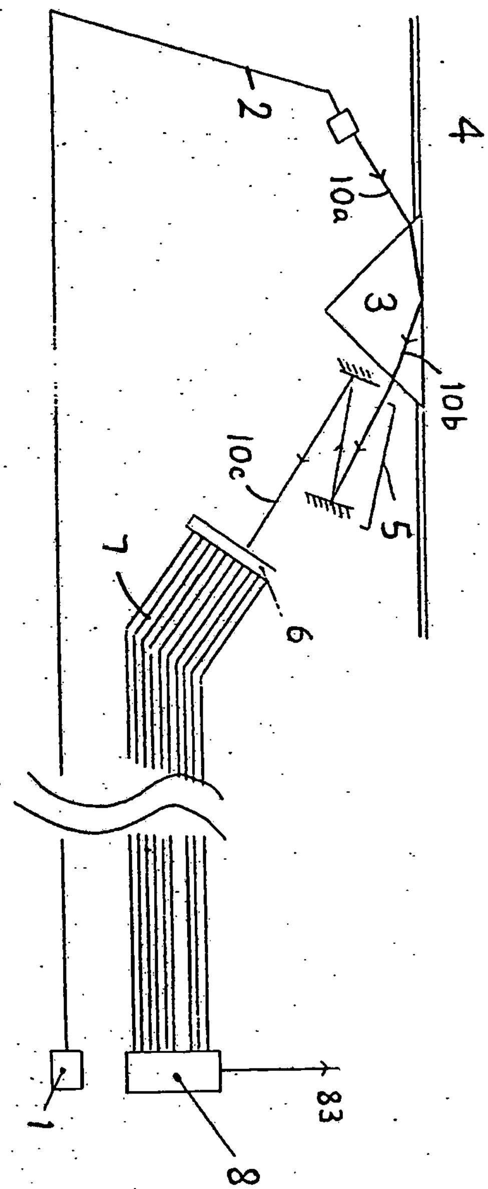


Fig. 2

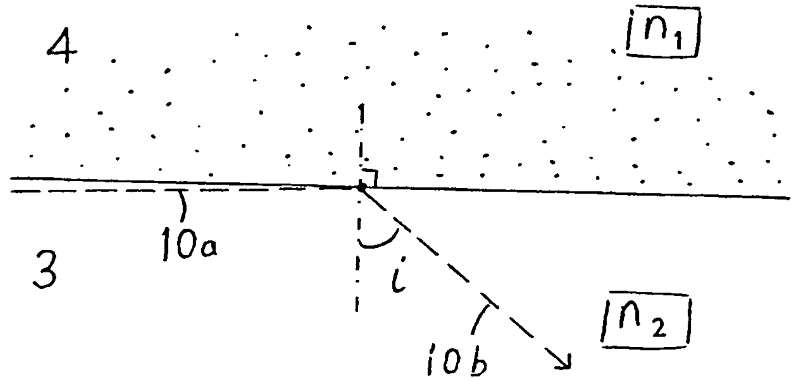
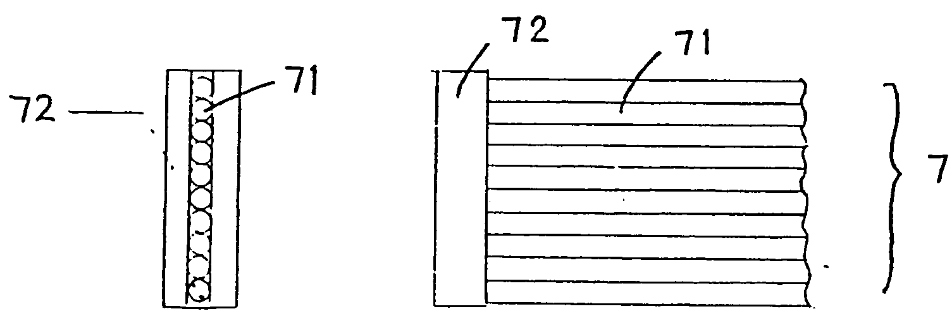


Fig. 3



19 NOV.86- 27611
DFA

2199404

3/3

Fig. 4

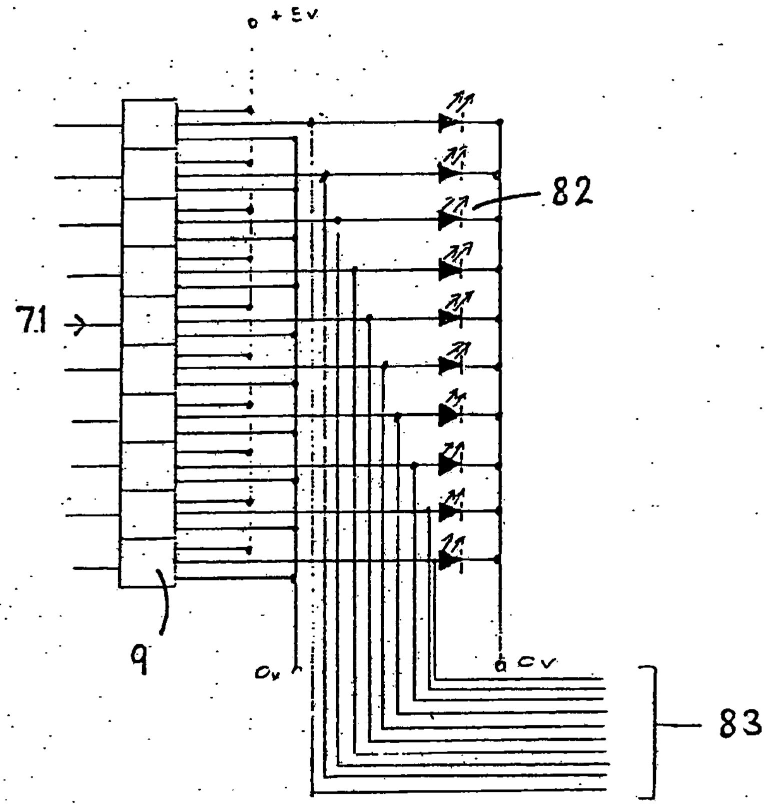
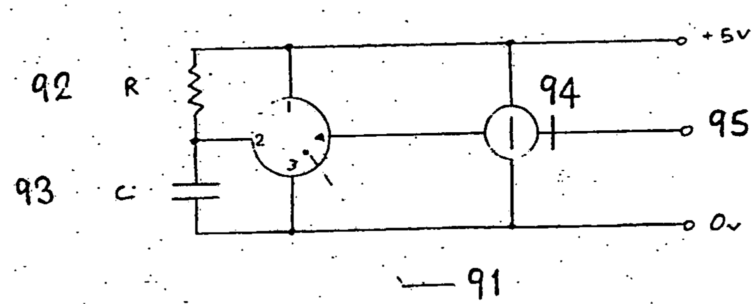


Fig. 5



2199404

Refractive Index Measuring Device

The present invention relates to a device for measuring the refractive index of a medium, for example of an oil emulsion.

According to the present invention, there is provided a refractive index measuring device comprising

a light source;

a prism, having a face in contact with a medium whose refractive index is to be measured, for receiving a light beam from the light source which is directed in such a manner that total internal reflection of the light beam occurs at said face; and

detecting means, comprising an array of optic fibres, for detecting the reflected light beam.

Preferably, decoding means, for generating electrical and/or optical signals indicative of the refractive index of the medium from light received by the detecting means, are also provided.

In an embodiment of the invention, the measuring device further comprises light guiding means such as an optic fibre for guiding a light beam from the light source into the prism.

Preferably, the array of optic fibres transmits the received light to the decoding means. Usually, but not necessarily, the optic fibres will be disposed side by side in a linear array.

Advantageously, means for extending the light path of the reflected light beam is located between the prism and the detecting means.

In one embodiment of the invention, the decoding means comprises a respective optical switch connected to each optic fibre of the detecting means and operable to generate an electrical signal in response to receiving an amount of light greater than a threshold amount. The electrical signals from the

optical switches may be directly used to activate display means, and/or processed by logic circuitry, to provide a measurement value of the refractive index.

Reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic diagram of a refractive index measuring device embodying the present invention;

Figure 2 illustrates the optical principle employed by the present invention;

Figure 3 illustrates an optical sensing head of the device of Figure 1;

Figure 4 is a circuit diagram for a decoder and display unit of the device of Figure 1; and

Figure 5 is a circuit diagram for an optical switch used in the decoder display unit of Figure 4.

The general arrangement of one embodiment of the invention is shown in Figure 1.

A light source 1 is provided for producing a light beam to be reflected from a medium 4 to be measured. The light source may be a monochromatic source such as an infra-red-emitting gallium arsenide laser diode, or a filtered polychromatic light source such as a filtered tungsten lamp.

A fibre optic cable 2 conducts light from the light source and directs it into a prism 3. The prism 3, made of a material such as glass or quartz, has one face exposed to the medium 4 whose refractive index is to be measured. The light is directed into the prism at such an angle (grazing the prism/medium boundary) that the light beam just undergoes total internal reflection.

Consequently a reflected light beam emerges from another face of the prism 3. The angle with which the light beam is reflected from the prism/medium

interface depends upon the refractive index of the medium 4 (such as an oil emulsion)

The reason for this is explained with reference to Figure 2. When a light ray 10a travels in a medium of refractive index n_2, directed substantially along the boundary with another medium having refractive index n_1 the light ray undergoes total internal reflection with an angle of reflection i which is called the critical angle. The critical angle depends upon the refractive indices of the media as follows:

$$\sin i = \frac{n_1}{n_2}$$

In this case the refractive index n_2 of the prism 3 can be considered constant, so that sin i depends only on the refractive index of medium 4. Therefore, slight changes in refractive index of the medium as might be caused by variations in the concentrations of constituents of the medium, for example the oil/water balance in an oil emulsion, produce slight alterations of the direction of the outgoing beam 10b from the prism. If a scale were placed perpendicular to the general direction of the beam these deviations would be revealed as transverse displacements along the scale. This is the principle used to measure the refractive index.

The reflected light beam 10b enters a light path extension apparatus 5. The apparatus 5 may consist for example of a pair of plane mirrors 51 and 52 separated by a certain distance occupied by air. The effect of the light path extension introduced by the apparatus 5 is to exaggerate the effect of angular changes in the direction of the beam, so that a considerable transverse displacement can be obtained

relative to the general beam direction without making the overall measuring device large in physical size.

An output beam 10c from the light path extension apparatus is incident upon an optical sensing head 6. The optical sensing head 6 includes a linear array of optical fibres, which form a fibre optic cable 7, and detected light signals are carried in one or more of the fibres of the cable 7 dependent upon where the light beam 10c was incident upon the sensing head 6. The linear array of optical fibres in the cable 7 thus represents a kind of scale for transverse displacements of the detected light beam.

The cable 7 is connected to a decoder and display unit 8, where the detected light signals are converted into display light signals, for providing a visual indication of light beam displacement, and also electrical signals for providing a digital reading.

The optical sensing head, and decoder and display unit, will now be explained in more detail with reference to Figures 3 to 5.

As shown in Figure 3 (a), the optical sensing head comprises a linear array or stack of optic fibres 71, for example ten in number, and a holder or carrier 72 for the stack of optic fibres which retains them in a straight, regular stack. The ends of the stack of optic fibres are presented to the light beam 10c so that light can enter them. Of course, the number and diameter of optic fibres 71 in the stack is chosen in accordance with the amounts of displacement of the reflected light beam to be expected in a particular application, and the accuracy of detection desired. As an example, the diameter of each fibre 71 may be 125μm.

The optic fibres 71 extend out from the carrier 72 as shown in Figure 3 (b), to form the cable 7.

The optical fibres of the cable 7 form optical

inputs of the decoder and display unit 8 illustrated in Figure 4. Each optic fibre 71 feeds into a respective optical switch 9 of the decoder and display unit 8. An optical switch is illustrated in more detail in Figure 5. It comprises a programmable light activated switch 91, for example a ZNP100 type device, a resistor 92, capacitor 93 and TTL gate 94. The TTL gate device 94 is connected between 0v and 5v power supply lines and has an output terminal 95. The resistor- capacitor network 92 and 93 determines the sensitivity of the optical switch.

If light is present in a given one of the optic fibres 71, this light shines upon the programmable light activated switch 91 of the respective optical switch 9, and if the quantity of light exceeds a certain amount, determined by the values of resistor 92 and capacitor 93, this causes the TTL gate 94 to turn on, giving a high logic level output signal at the output terminal 95. Ideally, the sensitivity of the optical switches is set so that ordinarily only one optical switch turns on in response to the light incoming along the fibre optic cable 7.

Referring again to Figure 4, it will be seen that the output terminals of each optical switch 9 are connected to respective light emitting diodes 82, and also to a parallel set of logic outputs 83. The light emitting diodes provide a visual display corresponding to the light signals conducted down the fibre optic cable 7 and allow a direct analogue type measurement to be taken by a user of the measuring device. For example the light emitting diodes 82 may be disposed in a line on the front panel of the measuring device, with a scale calibrated in refractive index values provided alongside. In addition, the logic outputs 83 can be fed to logic circuitry such as a microprocessor for

processing into a digital value indicative of the reflected light beam displacement, which may be further processed to give a value of the refractive index.

The present invention can be advantageously applied in situations where the refractive index changes are relatively small and difficult to detect by other means. For example, a device in accordance with the present invention is capable of detecting the refractive index changes caused by fluctuations in the concentration of oil in an emulsion of 5% oil and 95% water. These refractive index changes are of the order of 10^{-3} and below. A particular application is to monitoring of hydraulic fluid lines in underground mining machinery.

It will be understood that variations from the embodiment described above will be possible within the scope of the present invention.

The light source 1 may as mentioned be a source of monochromatic or filtered polychromatic light. In general the light beam produced need not be of a wavelength or wavelengths in the infra-red or visible range, but may be any form of electromagnetic radiation capable of being conducted along optic fibres and through a prism.

The illustrated embodiment employs a single optic fibre 2 conducting a single light beam from the light source to the prism. However, conceivably a number of optic fibres 2 could be provided which might allow a plurality of light beams to enter the prism at different points giving rise to different reflected beams. This could be of assistance in obtaining an accurate measurement. On the other hand, it might be possible to locate the light source directly adjacent the prism in such a manner that no optic fibre 2 was necessary. In this case a suitably unidirectional

light beam might be obtained by providing a slit or aperture between the light source and prism.

The prism illustrated in Figure 1 has a triangular cross-section but it is possible to provide a prism of a more complex shape, provided that it has a face in contact with the medium to be measured. For example a prism of a more complex shape might allow further internal reflections of the reflected light beam to take place before the light beam leaves the prism, for light path extension purposes.

The medium 4 may be an oil emulsion, in which case the measured value of refractive index gives an indication of the relative proportions of oil and water in the emulsion. However, the medium 4 may in general be any fluid for which changes in refractive index are required to be measured.

The light path extension apparatus 5 need not consist of a pair of plane mirrors but may have a more complex arrangement of several mirrors and/or a further prism or prisms or other optical elements, located in air or in any other medium. Alternatively the light path extension apparatus could be omitted altogether.

The optical sensing head 6 is a tightly packed linear array of optic fibres in the above embodiment, but this is not the only possible form of the sensing head. The optic fibres 71 could be spaced apart for the purpose of reducing or avoiding simultaneous detection of light in adjacent fibres simultaneously, which could occur if the reflected beam were spread out in the transverse direction. This might simplify subsequent processing of the electrical signals derived in the decoder and display unit 8. Also, if it proved advantageous for the light path extension apparatus or any other optical element to converge, diverge, or otherwise distort the output light beam 10c then this

could be taken account of in the design of the fibre optic array. For example a two-dimensional array of generally circular cross-section could be employed.

In the decoder and display unit 8, it is not necessary to provide both an analogue readout by light emitting diodes and also logic outputs for processing into a digital readout. Either type of readout may be sufficient on its own; also, the logic outputs could be used to drive an analogue-type display device if required. The optical switch 9 need not have exactly the structure shown in Figure 5 but could comprise any suitable opto-electronic arrangement capable of converting incident light from an optic fibre into a logic signal.

It is even possible to dispense with the decoder and display unit altogether, and simply to use the light detected in the optic fibres 71 directly to provide a display. For example the ends of the fibres 71 could be led out to the front panel of the measuring device, providing one or more illuminated dots indicative of the refractive index.

Claims:

1. A refractive index measuring device, comprising:

a light source;

a prism, having a face for contact with a medium whose refractive index is to be measured, for receiving a light beam from the light source which is directed in such a manner that total internal reflection of the light beam will occur at said face; and

detecting means, comprising an array of optic fibres, for detecting the reflected light beam.

2. A device as claimed in claim 1, further comprising:

light guiding means such as an optic fibre for guiding a light beam from the light source into the prism.

3. A device as claimed in claim 1 or 2, further comprising:

decoding means, for generating electrical and/or optical signals indicative of the refractive index of the medium from light received by the detecting means.

4. A device as claimed in claim 3, wherein the array of optic fibres is arranged to transmit the received light to the decoding means.

5. A device as claimed in any preceding claim, wherein the optic fibres of the detecting means are disposed side by side in a linear array.

6. A device as claimed in any preceding claim, wherein means for extending the light path of the reflected light beam are located between the prism and the detecting means.

7. A device as claimed in claim 3 or 4, or claim 5 or 6 as appended to claim 3 or 4, wherein the

decoding means comprises a respective optical switch connected to each optic fibre of the detecting means and operable to generate an electrical signal in response to receiving an amount of light greater than a threshold amount.

8. A refractive index measuring device, substantially as hereinbefore described with reference to the accompanying drawings.

Published 1988 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office, Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd, St Mary Cray, Kent. Con. 1/87.